# Prototype Expert System to Assist with the Stabilization of Neonates Prior to Transport

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*The transport of sick or premature newborns from community hospitals to acute care facilities is often necessary for the infants to receive the level of care required. Prior stabilization of these infants is imperative to a successful transport. The knowledge required to treat and stabilize sick and premature newborns is specialized and may not be available in community hospitals. 'The S.T.A.B.L.E. Assistant" is a prototype rule based decision support system based on the educational program "Transporting Newborns the S.T.A.B.L.E. Way"[3]. 'The S.T.A.B.L.E. Assistant" accepts clinical information related to an infant's breathing status, blood glucose status and selected lab values and provides instructions as to what interventions are needed to stabilize and prepare the infant for transport. The computerized program was evaluated using data collected from 19 charts of newborns requiring transport from a community hospital to a tertiary care center. Patient data were entered into the computerized program and the subsequent instructions were reviewed by a group of neonatology and neonatal transport experts. Reviewers evaluated 'The S.T.A.B.L.E. Assistant" for the safety of the program, the extent to which the computerized program follows the educational program guidelines and the degree to which the instructions generated are within the scope of community caregivers' practice. Results were positive, indicating 'The S.T.A.B.L.E. Assistant" prototype is safe, and within the guidelines of neonatal clinical practice.*

## INTRODUCTION

The mortality of sick and premature infants has declined dramatically with the advent of regionalized perinatal care systems and the development of neonatal intensive care facilities [1]. However, transport of the sick or premature newborn from a community hospital to an acute care facility is often necessary for the infant to receive the required care. Because their physical reserves are minimal and their condition can deteriorate rapidly newborns must be stabilized before transport.

Personnel at outlying and community hospitals can contribute to the stabilization of newborns prior to transport, but must know the appropriate clinical actions. Increasing their awareness and knowledge of clinical needs and potential problems of sick and premature newborns can have a significant impact on the decline of infant mortality and morbidity of transported infants [2]. One potential method for educating personnel in outlying hospitals in and expert system. Expert systems are useful tools for providing clinicians the high level knowledge related to neonatal transport in settings where neonatal experts are not readily accessible.

A prototype expert system was created based on the guidelines and standards presented in the educational manual *Transporting Newborns the S.T.A.B.L.E. Way* [3] and on expert contribution. The educational manual includes five physiological areas (blood glucose "S", body temperature "T", artificial breathing "A", blood pressure "B", and lab work "L") and one psychosocial area (emotional support of infant and family "E") that need to be addressed before transport of the newborn. The prototype expert system focuses on three of the physiological areas (blood glucose, artificial breathing, and lab work).

## BACKGROUND

Transport of sick and/or premature neonates often is imperative to their survival. Transporting infants from community hospitals to tertiary care centers allows them to receive a higher level of care that may not be available in the community hospitals. Several studies indicate the importance of stabilizing the newborn before transport to decrease transport related infant mortality and morbidity [1,2,4]. Personnel at referring institutions are the first caregivers to recognize an infant who will require transport to a tertiary center and are the first clinicians available to begin stabilization of the infant [4]. However, the stabilization of sick, premature or very low birth weight infants often requires expertise in neonatal care [1,2] which is not always available at community hospitals.

Decision making is an integral part of patient stabilization. The process of decision making is complex, weaving learned skills with intuition and

clinical judgment. Intuitive judgment is one distinguishing factor between expert human judgment the judgment of novices [5].

The availability of expert knowledge in any field, neonatal transport included, often is limited due to the number of experts that exist, the location of the expert, or the time at which the expert knowledge is required. If an expert is not available when a critical decision is required a computerized expert system may provide an alternative to a human expert. The knowledge of an expert or panel of experts can be accessed via an expert system and used by others in making decisions and solving problems.

The importance of recognizing expert systems as a tool to improve the clinician's ability to make decisions is emphasized throughout the literature [6]. In both nursing and medicine, the unrealistic expectation has developed that the clinicians must carry extremely large amounts of clinical knowledge in memory. Encoding computer systems with the knowledge and logical thinking of domain experts may be helpful to clinicians trying to manage large amounts of knowledge. Instead of mastering every pertinent fact within a specialty, a professional may learn the basic principles and problem solving skills to a particular domain and use the computer for extensive memory support [7]. This approach allows clinicians to take advantage of the superior accuracy, reliability and speed of knowledge recall of an expert system rather than rely on their own memory [8].

In healthcare, the ultimate responsibility for decisions suggested by expert systems rests with the clinician. The professional must have enough knowledge of the domain to assess the correctness of the system's recommendations and then to take appropriate actions [7]. Expert systems can work through clinicians to improve, but not replace clinical judgment [6].

## METHODS

### Knowledge Acquisition

Karlsen's educational manual, *Transporting Newborns the S.T.A.B.L.E. Way* [3], provided the organizational structure of the knowledge acquisition for the prototype expert system titled, *The S.T.A.B.L.E. Assistant*. Rules included in the expert system are based on the guidelines and standards presented in the *S.T.A.B.L.E.* educational manual. The content of the *S.T.A.B.L.E.* educational program is considered to be expert knowledge. The *S.T.A.B.L.E.* educational program is founded on accepted standards and practices in the field of neonatal care, and has been reviewed by numerous neonatologists,

neonatal nurse practitioners, neonatal transport nurses, and newborn intensive care staff nurses. Reviewers have accepted the educational program as being both complete and accurate [3]. Ms. Karlsen granted approval for the use of her material in the computerized program and was the primary expert involved with system development.

Rules of the computerized program follow a traditional IF/THEN structure. In *The S.T.A.B.L.E. Assistant*, if the clinical data meets the conditions of the IF statement the premises is considered true and the rule is fired. When a rule is fired, the action of the THEN statement of that particular rule is executed.

Initial rules for the computerized program were derived from the information contained in the educational manual and refined according to the expert's knowledge. The expert and knowledge engineer reviewed the premise and conclusion of each rule and discussed changes needed for the rule. When the expert needed assistance with a specific rule, she and the knowledge engineer consulted other references in neonatal care and transport such as *The Harriet Lane Handbook* [9] and the *Perinatal Continuing Education Program* educational manual [10]. The development of the knowledge base transpired over eight months of frequent meetings between the expert and the knowledge engineer. Knowledge acquisition continued throughout the development of the computerized program until the evaluation phase.

### Programming and Rule Development

**Setting.** The expert system was developed in *VP-Expert* (Wordtech Systems [11]), a rule-based expert system development tool which runs on personal computers running MS-DOS. *VP-Expert* was chosen because it offers simple English-like rule construction, a forward and backward chaining inference engine, knowledge base "chaining" (allowing larger knowledge bases), and the ability to exchange data with dBASE compatible files, 1-2-3 or Symphony worksheet files, and ASCII text files. *VP-Expert* also contains commands to explain actions taken during a consultation and provides optional windows to observe the inference engine as it navigates the knowledge base to solve problems. The structure of programs written in *VP-Expert* includes: an ACTIONS block which organizes and directs the flow of the program; the rules, listed in an order determined by the programmer; and the ASK statements, which are used when needing to ask the user for data not contained in the database at run time.

The purpose of the program was to gather specific clinical information and present interventions necessary to stabilize an infant's condition. Therefore, the program primarily used the forward chaining function of the software. Chaining of the knowledge bases was not necessary for the program, and a database of the patient clinical information is not accumulated from run to run.

**Method.** For the programming of *The S.T.A.B.L.E. Assistant*, the order of the modules Sugar, Artificial Breathing, and Lab Work was altered slightly from the educational program. The educational program has been criticized because the mnemonic, although easily understood and remembered, does not address the most life threatening physiological areas first. The knowledge engineer and the expert decided to list Artificial Breathing before Sugar in the computer program so that potentially more serious problems would be addressed before other problems that are not as life threatening.

**Artificial Breathing.** Evaluation of an infant's respiratory status considers several factors. The infant's respiratory rate, respiratory effort, color, and oxygen requirements are all important in determining an infant's respiratory status and recommended actions. Conditions considered by rules must be clearly defined. For clarification and simplification respiratory effort and current FiO2 were evaluated and assigned a numeric code. These codes as well as respiratory rate and color were used by the expert system when making a decision related to respiratory support.

The Artificial Breathing rules were organized into six areas. The areas include *Assignment of O2 Class, Blood Gas Evaluation, Assignment of WOB (work of breathing), Assignment of Respiratory Status, Normal Respiratory Status, Mild Respiratory Distress,* and *Moderate Respiratory Distress.*

The rules included under *Assignment of O2 Class* consider the infant's oxygen saturation by pulse oximetry or arterial PaO2 and current FiO2. The rules included under *Assignment of WOB* consider the respiratory effort of the infant as reported by the caregiver.

The rules included in the *Assignment of Respiratory Status* considered the WOB coded variable, the infant's respiratory status, the infants hematocrit and elements of a blood gas (pH and PCO2) to determine needed interventions. A combination of rules was required in this section because of variation in response to an infant's work of breathing. If the infant's breathing effort is easy and non-labored, other information such the infants

color, FiO2 and respiratory rate still must be considered . However, if the infant's respiratory effort is significant and includes signs of severe or critical respiratory distress such as grunting, nasal flaring or retractions, or the infant is apneic, interventions can be determined without consideration of the infant's color and FiO2. Rules containing information related to interventions needed for infants in severe or critical respiratory distress are included in the *Assignment of Respiratory Status* section. These rules could have been separated, and put into a *Severe/Critical Respiratory Distress* section, but the resultant slower processing time may be detrimental.

The rules contained in the *Normal Respiratory Status, Mild Respiratory Distress,* and *Moderate Respiratory Distress* sections consider the coded respiratory status variable assigned in the *Assignment of Respiratory Distress* section, the infant's color, and the coded variable assigned in the *Assignment of O2 Class* section. From these variables, the rules determine what interventions are necessary to support the infant's respiration before transport.

The *Blood Gas Evaluation* section includes rules that consider the pH, PaO2, and PCO2 from an arterial blood gas. The rules found at the top of the Artificial Breathing Module evaluate a blood gas if one is available. However, since newborn arterial blood gases may not be easily available at community hospitals due to the difficulty in drawing them, the effort of this project was concentrated on interventions based on physical assessment of the infant. The premises for the rules contained in the *Blood Gas Evaluation* section were obtained from the *S.T.A.B.L.E.* educational manual. The conclusions were obtained either from the educational manual or from the expert.

A total of 70 rules are included in the Artificial Breathing Module, with most rules (20) residing in the *Assignment of Respiratory Status* area.

**Blood Glucose.** The target range for a neonatal blood glucose is 50-100 mg/dl. Interventions are needed for blood glucoses between 40-50 mg/dl and for less than 40 mg/dl. Information related to the interventions necessary for infants with blood glucoses greater than 150 also was included. If the blood glucose is unknown, a rule is included in the Sugar module of the knowledge base alerting the user to the need of a least one blood glucose before transport. Knowledge related to blood glucose management is represented in six rules.

**Lab Work.** Blood cultures, a complete blood count (CBC) with differential, blood glucose, and a blood

gas are recommended for neonates before transport. Interventions for blood glucose and blood gas results are included in the Artificial Breathing and Sugar modules. Interventions for blood culture and CBC results are included in the 13 rules of the Lab Work module.

Obtaining a CBC with differential before the infant is transported to evaluate the infant's infection status is important. From the CBC, an absolute neutrophil count (ANC) and an immature to total white blood cell ratio (I/T) is calculated. The ANC and I/T ratio provides valuable information related to potential sepsis in the infant. A low ANC for the infant's age indicates the infant is fighting an infection and depleting its total number of neutrophilic white blood cells. With the I/T ratio, a value above 0.3 indicates sepsis should be suspected, while a value above 0.8 indicates a higher risk of death due to sepsis [3]. Rules were written in the Lab Work module to calculate the ANC and I/T ratio, and then to evaluate the infant's status of infection.

Another important reason to obtain a CBC before transporting an infant is to evaluate the platelet count and to determine the infant's risk of hemorrhage. Appropriate interventions are suggested for platelet counts below 100,000/$\mu$L.

## EVALUATION

Structural testing and static validation occurred throughout the development of the computerized program. As each rule was written it was tested individually for unique naming and syntax errors. The content of each rule was carefully reviewed frequently throughout the development by the expert and the knowledge engineer. Any mistakes or confusing points in the premises or conclusions of the rules were corrected. A test scenario including combinations of values aimed at firing each rule at least once was developed. *VP-Expert* allows the developer to enter data and observe the inference engine as navigation through the knowledge base occurs during a consultation. This feature was utilized with the test scenario to test the rules and their method of firing.

Functional testing and dynamic validation of the prototype system was evaluated using patient information collected from charts of newborns transported from a community hospital to a tertiary care center. Patient data from 19 charts were entered into the computerized program and the subsequent instructions were reviewed by a group of neonatology and neonatal transport experts.

Reviewers were asked to evaluate the instructions generated by the prototype for each set of patient data. The instructions generated were evaluated for 1) degree of safety for use in patient care, 2) extent to which the instructions generated by the computerized program followed the guidelines and standards of the education program, and 3) degree to which the instructions generated were within the scope of a community caregiver's practice. A seven point Likert scale (1=Absolutely Disagree, 7=Absolutely Agree) was used to collect the reviewer's evaluation of the three areas. Reviewers were also asked to provide feedback related to the potential usefulness of a decision support system like *"The S.T.A.B.L.E. Assistant"* when stabilizing newborns for transport.

## RESULTS

Structural testing found all rules to be correct in syntax, unique in name and action, complete, consistent, and not circular. Rules are not isolated and they do not conflict with each other. Each rule fired appropriately, in the correct order.

Functional testing revealed the computerized program to be within the specifications outlined for the project. Means, ranges and standard deviations for each of the three evaluation points are found in Table 1.

Table 1. Expert System Evaluation

|  | Mean | Std. Dev. | Min-Max | Median | Mode |
|---|---|---|---|---|---|
| Safety | 5.77 | 1.75 | 1.00-7.00 | 7.00 | 7.00 |
| Standards | 6.33 | 1.24 | 1.00-7.00 | 7.00 | 7.00 |
| Scope | 6.98 | 0.13 | 6.00-7.00 | 7.00 | 7.00 |

(1 = Absolutely Disagree, 7 = Absolutely Agree)
n = 19

The safety score was affected by one set of patient data in which the reviewers felt the computerized program, and the educational program guidelines, did not suggest adequate interventions and scored it quite low. Exclusion of this case raises the mean safety score to 5.96 with a range of 5.00 to 7.00.

Reviewer responses to the usefulness of a decision support system such as *"The S.T.A.B.L.E. Assistant"* when stabilizing newborns for transport were varied. The reviewers recognized the advantage of having a system that would provide knowledge that might not otherwise be available in community centers. They also saw the benefit of a system that could be used to prompt clinicians with information that may have been forgotten. Concerns related to the usefulness of *"The S.T.A.B.L.E. Assistant"* centered

on the difficulty of including intuition in the decision making process of the computerized system, the potential lack of personal contact between referral center and tertiary care center, and the amount of time needed to use the decision support system at the point of care.

Additional comments supplied by the reviewers encouraged the inclusion of more data points, such as hemoglobin, hematocrit, blood pressure, and temperature, for evaluation by the system during the stabilization process. Reviewers were also asked to provide feedback related to the potential usefulness of a decision support system like *The S.T.A.B.L.E. Assistant* when stabilizing newborns for transport.

## DISCUSSION

The implementation of a prototype expert system to assist with the stabilization of neonates for transport was successful. Knowledge related to the field of neonatal transport was captured and organized in a useful manner.

Several issues influenced the overall outcome of the prototype system. The inclusion of only three physiologic areas precluded collection of some data points that may be important in determining a conclusion for a rule. For example, the status of an infant's blood pressure or temperature often influences the interventions needed to support the infant's breathing.

Overall *The S.T.A.B.L.E. Assistant* received a good evaluation from the reviewers. The safety score was high, but not perfect. Before implementing the system in a clinical setting issues related to the safety of the program must be addressed. Clinical issues dealt with by this program directly affect patient outcomes, so safety levels need to be as close to a perfect (7.00) as possible. Cases such as the one with a low safety rating need to be closely studied and adequate changes and/or additions made.

Completing the computerized program to include other aspects of the infant's care such as blood pressure and temperature management may improve the safety rating. Further development and refinement of the system should also improve the computerized program's safety and usefulness during infant stabilization.

*The S.T.A.B.L.E. Assistant* is not currently implemented in a clinical setting. It is not entirely useful in clinical settings until the other modules (blood pressure, temperature and emotional support) are completed. In addition, *The S.T.A.B.L.E. Assistant*, would be most useful if integrated into an existing database used at the point of care during the stabilization process to minimize the time required for

data during the busy stabilization period.

Further development of *The S.T.A.B.L.E. Assistant* is pending procurement of additional funding. However, a method of organizing data points needed for decision making while stabilizing newborns for transport has been identified and will be useful as a foundation for subsequent development.

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